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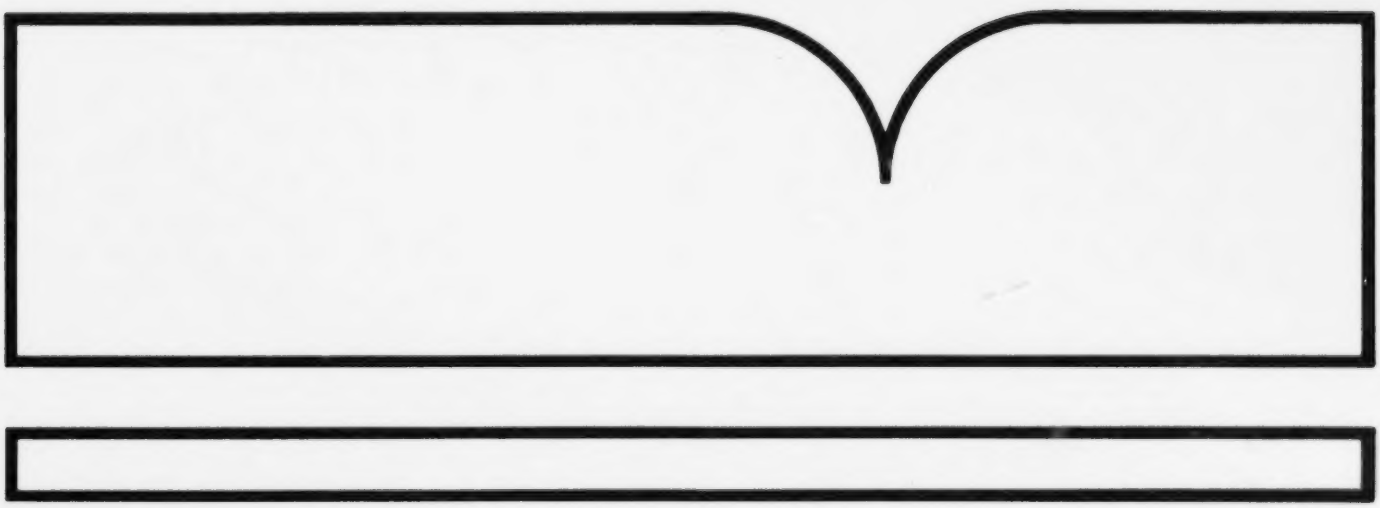
Source Category Survey: Borax and Boric Acid Industry

Acurex Corp.
Morrisville, NC

Prepared for

Environmental Protection Agency
Research Triangle Park, NC

May 80



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16. ABSTRACT

Background information is presented on the borax and boric acid industry for the purpose of determining the need for a new source performance standard (NSPS). The industry is surveyed and categorized by plant, process, and other factors. Information is presented on the processes, emissions, and air pollution control equipment. State and local regulations are summarized. The impact of a potential NSPS on particulate emissions is discussed.

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Office of Air Quality Planning and Standards
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1. SUMMARY

The Clean Air Act, as amended in 1977, calls for the promulgation of emissions standards of performance for new and modified sources (NSPS's) that contribute significantly to air pollution. The borax/boric acid source category has been tentatively identified as having such a potential.

The borax/boric acid source category includes those facilities used in refining and processing either sodium or calcium borate ores or brines to produce boric acid and other borate compounds. Facilities processing refined borax to produce boric acid are also included, as are the facilities processing the byproduct sodium sulfate resulting from boric acid production. Not included, however, are associated mining, screening, crushing, or grinding operations.

The category, as a result, consists of six plants operated by four companies:

U.S. Borax and Chemical Corp.	Boron, CA
	Wilmington, CA
Kerr-McGee Chemical Corp.	Trona, CA
	Westend, CA
American Borate Co.	Lathrop Wells, NV
Stauffer Chemical Co.	San Francisco, CA

The U.S. Borax plant at Wilmington, California is scheduled to cease production of boric acid in 1980, when it will be replaced by a new production unit at U.S. Borax in Boron, California.

The production of borax/boric acid expressed in terms of B_2O_3 content was 706 Gg (778,000 tons) in 1978 and is expected to grow through the 1980's at 2.3 percent per year, the historical annual growth rate of the past 20 years. The increased production will be met through increased utilization of existing facilities and the new boric acid unit at Boron, rather than other new or modified facilities between 1980 and 1985.

The refinement and production of borate compounds involves purification and crystallization processes to either isolate the borates brom brine or remove clay and shale contaminants from crude ore. Purified crystals are often calcined to form a powdered product and can be dehydrated in furnaces to form anhydrous borates. Boric acid is produced from either brine or refined borax by acidification processes.

The main pollutant of concern in this category is particulate matter. Particulates are emitted from the furnaces, calciners, and coolers following the product dryers. Particulate matter is also emitted in the form of fugitive emissions from material handling. Additionally, boric acid vapors are released from the digesters during boric acid production.

Control of particulate matter is accomplished primarily by scrubbers on the furnaces, calciners, and coolers. Scrubbers are also used to control boric acid vapors. Fabric filters, although used on furnaces and dryers, have been found to be more difficult to operate than scrubbers and are in some cases being replaced by scrubbers. Electrostatic precipitators that are used at only one plant, have also been found to be less effective

than scrubbers, because of high particle resistivity associated with boron compounds.

Present California and Nevada air pollution control regulations typically limit particulate emissions to 0.46 g/nm^3 (0.2 gr/dscf) and 20 percent opacity which requires approximately 94 percent control efficiency. Data supplied by state and local agencies indicate that this is being achieved. As a result, the emissions of particulate matter for the borax and boric acid source category are estimated to be 619 Mg (682 tons).

The impact of developing an NSPS for this source category on nationwide particulate emissions in 1985 is estimated to be zero because of increased utilization of existing production capability.

Therefore, it is recommended that a standard for this source category not be developed.

2. INTRODUCTION

The Clean Air Act (CAA), as amended in 1977, provides authority for EPA to control discharge of pollutants into the atmosphere. The Act contains several regulatory and enforcement options for control of emissions from stationary sources. Options include (1) National Ambient Air Quality Standards (NAAQS's) on the national level and State Implementation Plans (SIP's) on the state level, (2) NSPS's and (3) National Emission Standards for Hazardous Air Pollutants (NESHAP's).

Section 111 of the CAA calls for promulgation of NSPS's for new and modified sources that may contribute significantly to air pollution -- emissions that could endanger public health and welfare. The standards must reflect the best degree of control as satisfactorily demonstrated to EPA (taking cost, energy, and non-air environmental quality impacts into account). This source category survey is the first step in the process of setting an NSPS for borax and boric acid. Its primary purpose is to verify whether or not a standard is warranted and, if so, to determine the availability of data required to set a standard.

The necessary information for the source category survey was gathered through the following sources:

1. Population and growth rates from literature searches, contacts with federal agencies, data from individual states, and discussions with industry representatives

2. Data on emissions and applicable control devices from literature searches, National Emissions Data System (NEDS), contracts with federal, state, and local air pollution control agencies, records of the agencies, contacts with industry representatives, and site visits to four plants
3. State and local regulations from contacts with the authorities who are responsible for air pollution control in the area

An important factor throughout the information collection, analysis, and documentation effort has been the relationship between the borax/boric acid source category and the nonmetallic mineral processing source category. For this study, the issue has been resolved by identifying borax facilities as the dryers, furnaces, kilns, and coolers used in the preparation of anhydrous and hydrated borax. Boric acid is defined to include all processes in the manufacture of anhydrous or hydrated boric acid except materials handling and grinding processes. The effect of such a definition is that crushers, grinding mills, screening operations, bucket elevators, conveyor transfer points, bagging operations, storage bins, and fine product truck and rail loading stations are not addressed in the borax/boric acid source category but are addressed in the nonmetallic mineral processing source category.

Secondary manufacturing processes, which range from simple mixing of borax with detergents to large, complex glass manufacturing operations, are not included in the source category survey. To do so would necessitate considering many unrelated sources having different emission problems, control problems, and economic characteristics.

3. CONCLUSIONS AND RECOMMENDATIONS

The borax/boric acid industry, which is concentrated in the desert region of Southern California/Nevada, consists of six plants owned by four companies. One company produces over 75 percent of the borate products produced in the United States.

Although exact production levels of each compound are confidential, the production of borates expressed in terms of B_2O_3 content was 706 Gg (778,000 tons) in 1978. While this represented a 6 percent annual growth rate over the preceding 5 years, industry analysts project growth to follow the historical rate for borate compounds of 2.3 percent per year over the next 10 years.

The most recent industry expansions to be completed in 1979 and 1980 will increase the industry production capability from 706 Gg/yr (778,000 tons/yr) to 848 Gg/yr (934,000 tons/yr). The effect of these expansions is to encourage a no-growth situation in the near future since the 1980 production capacity is sufficient to meet the anticipated production of 804 Gg (886,000 tons) B_2O_3 in 1985.

Data supplied by state and local air pollution control agencies indicate that the degree of control, 94 percent, required by present regulations is being met. These regulations typically require that particulate emissions not exceed 0.46 g/nm^3 (0.2 gr/dscf) and 20 percent

opacity. The particulate emissions for the source category, therefore, are estimated to be 619 Mg (682 tons).

If an NSPS standard for borax/boric acid were developed, the reduction in particulate emissions in 1985 is estimated to be zero due to increased utilization of existing facilities. It is recommended, therefore, that no further action be taken at this time regarding development and promulgation of an NSPS for borax/boric acid.

4. INDUSTRY DESCRIPTION

4.1 SOURCE CATEGORY

Borax and boric acid belong to a group of chemical compounds known as borates, all of which contain the component B_2O_3. Borax, a sodium borate, is the most common naturally occurring compound. It occurs both as the mineral tincal and in lake brines. The chemical formulas of the naturally occurring borates with commercial value are as follows:

Tincal	$Na_2B_4O_7 \cdot 10H_2O$
Tincalconite	$Na_2B_4O_7 \cdot 5H_2O$
Kernite	$Na_2B_4O_7 \cdot 4H_2O$
Colemanite (borocalcite)	$Ca_2B_6O_{11} \cdot 5H_2O$
Ulexite (boronatrocalcite)	$NaCaB_5O_9 \cdot 8H_2O$
Probertite	$NaCaB_5O_9 \cdot 5H_2O$
Priceite	$Ca_5B_{12}O_{23} \cdot 7\text{-}1/2H_2O$
Pandermite	$Ca_4B_{10}O_{19} \cdot 7H_2O$
Boracite (stassfurite)	$Mg_3B_7O_{13} \cdot Cl$
Sassolite (natural boric acid)	H_3BO_3
Szaibelyite (ascharite)	$MgBO_2(OH)$

The borax/boric acid source category includes those facilities which are used in the refining and processing of either sodium or calcium borate ores or brines to produce boric acid and other borate compounds. The

facilities processing the byproduct sodium sulfate resulting from boric acid production are also included. Not included, however, are any associated mining, screening, crushing, or grinding operations used on either crude ore or borax products. The standard under development for nonmetallic mineral processing will apply to these processes. Secondary or end-use processes of borax and boric acid are also not included, due to differences in emissions, controls, and economic characteristics. The exceptions to this are the facilities processing refired borax to produce boric acid.

4.2 INDUSTRY BACKGROUND INFORMATION

The United States is the leading world producer of borate compounds. Production in 1977 expressed in terms of borate (B_2O_3) content was 667 Gg (735,000 tons), which constituted 53 percent of the world production for that year.[1,2] U.S. production of borate compounds in 1978 was 706 Gg (778,000 tons) B_2O_3. Although this represents a 6 percent per year increase in production over the past 5 years, industry analysts project growth in the future to be much slower. Based on the historical growth in production over the past 20 years of 2.3 percent per year, production in the year 1985 is estimated to be 804 Gg (886,000 tons) of B_2O_3.[2] The increase in production rate will be met through increasing utilization of the new capacity level as of 1980. Recent industry expansions, to be completed in 1979 and 1980, will increase production capacity from 706 Gg (778,000 tons) to 848 Gg (934,000 tons). No other expansions are anticipated in the next five years. Table 4-1 summarizes these changes in capacity and production levels. Borate compounds are used in a wide variety of manufacturing applications, including the manufacture of glass,

laundry products, and flame proof cellulosic insulation. A more complete list of borate mineral and compound uses is presented in Figure 4-1.

Table 4-1. SUMMARY OF THE BORAX/BORIC ACID INDUSTRY CAPACITY AND PRODUCTION LEVELS

(Gg (thousand tons))

Year	Capacity	B_2O_3 content production
1978	706 (778)	706 (778)
1980	848 (934)	739 (814)
1985	848 (934)	804 (886)

Borate compound processing is done by three companies at facilities located in the vicinity of Death Valley, California. The nature of the recovery and refining processes dictate that almost all of these processes be done at or near the deposit sites. Since boric acid and anhydrous borax both may be produced from calcined borax, it is feasible to process these compounds offsite, as is currently done at U.S. Borax's Wilmington plant and the Stauffer Chemical Company boric acid processing plant in San Francisco. No other offsite processing plants exist.

Table 4-2 summarizes the products produced at each of the borate compound processing sites operated by these companies. U.S. Borax Chemical Corp., a subsidiary of Rio-Tinto Zinc Corp., is the largest producer of borate compounds; more than 75 percent of the borate compounds produced in the United States are produced by U.S. Borax.[1] At their facilities in Boron, California, tincal ore is processed to produce

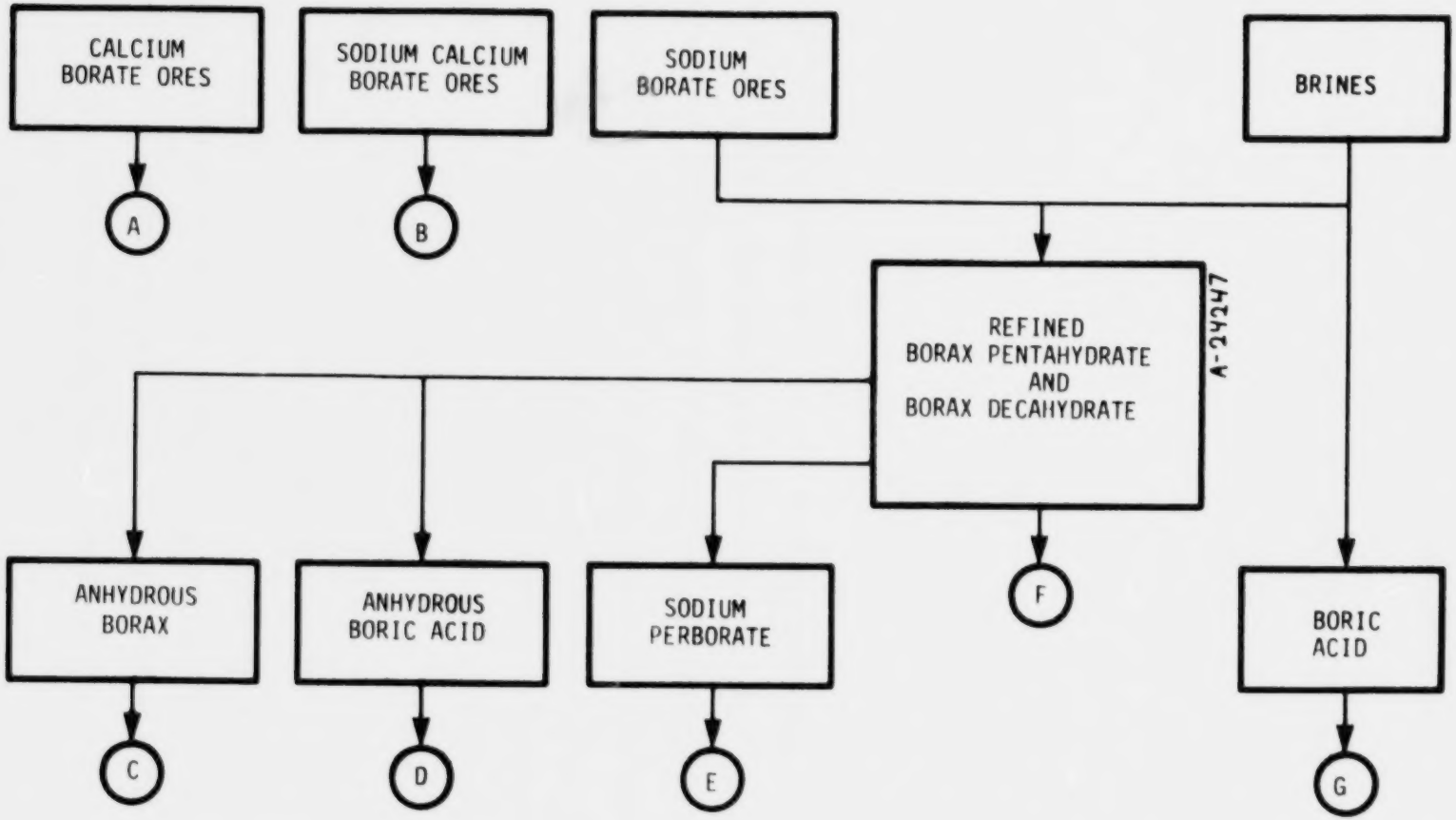


Figure 4-1. Principal uses of boron minerals and chemical compounds in the United States.

A	B	C	D	E
GLASS	CELLULOSE INSULATION	FERTILIZERS	ANTISEPTICS COSMETICS	DETERGENTS AND BLEACHES
METALLURGY	FIBERGLASS INSULATION	FIBERGLASS	FIRE RETARDANTS	DISINFECTANTS
NUCLEAR	METALLURGY	GLASS	COTTON MATRESS	TEXTILE BLEACHES AND DYES
TEXTILE GLASS FIBERS	NUCLEAR	METALLURGY	PARTICLE BOARD	
		VITREOUS ENAMEL FRITS AND GLAZES	GLASS	
			INSECTICIDES	
			METALLURGY	
			NYLON	
			PHOTOGRAPHY	
			TEXTILE TREATING	
			SOAPS AND DETERGENTS	
			VITREOUS ENAMEL FRITS AND GLAZES	

F		G
ADHESIVES, STARCHES	GLASS	ANTISEPTICS
CEMENT	HERBICIDES	COSMETICS
CORROSION INHIBITORS	INSECTICIDES	FIRE RETARDANTS
COSMETICS, DRUGS	LEATHER TANNING	CELLUOSIC INSULATION
ELECTRICAL INSULATION	METALLURGY	MATRESS PAINTS
ELECTROLYTIC REFINING	PHOTOGRAPHY	GLASS
FERTILIZERS	SOAPS AND DETERGENTS	INSECTICIDES
FIBERGLASS INSULATION	TEXTILE DYES	METALLURGY
FIRE RETARDANTS	WAX EMULSIFIERS	NUCLEAR
CELLUOSIC INSULATION	WOOL PRESERVATIVES	NYLON
COTTON MATTRESS	VITREOUS ENAMEL	SOAPS AND DETERGENTS
PARTICLE BOARD	FRITS AND GLAZES	TEXTILE TREATING
		TEXTILE GLASS FIBERS
		VITREOUS ENAMEL FRITS AND GLAZES

Notes to Figure 4-1.

Table 4-2. BORAX/BORIC ACID INDUSTRY SUMMARY

Company	Plant location	Raw materials	Principal products
U.S. Borax	Boron, CA	Tincal Kernite	Borax pentahydrate ($Na_2B_4O_7 \cdot 5H_2O$) Borax decahydrate ($Na_2B_4O_7 \cdot 10H_2O$) Anhydrous borax (pyrobor) ($Na_2B_4O_7$) Boric acid[a] (HBO_3) Anhydrous boric acid (boric oxide)[b] (B_2O_3) Rasorite® 46 (crude borax pentahydrate)
U.S. Borax	Wilmington, CA[b]	Refined borax	Boric acid (HBO_3) Anhydrous boric acid (B_2O_3)
Kerr-McGee	Trona, CA	Searles Lake brine	Boric acid (HBO_3) Anhydrous boric acid (B_2O_3) Borax pentahydrate ($Na_2B_4O_7 \cdot 5H_2O$) Borax decahydrate ($Na_2B_4O_7 \cdot 10H_2O$) Sodium sulfate (Na_2SO_4)
Kerr-McGee	Westend, CA	Searles Lake brine	Boric acid (HBO_3) Anhydrous boric acid (B_2O_3)
American Borate	Lathrop Wells, NV	Colemanite ore Ulexite/Probertite	Calcined and uncalcined colemanite ($Ca_2B_6O_{11} \cdot XH_2O$) Refined Ulexite/Probertite ($NaCaB_5O_9 \cdot XH_2O$)
Stauffer Chemical	San Francisco, CA	Refined borax	Boric acid (HBO_3)

[a]Not yet online, expected to start production in early 1980's.
[b]To be shut down when Boron plant begins boric acid production.

refined boraxes, anhydrous borax, boric acid, and several specialty products. Kernite ore is presently used in the production of crude sodium pentaborate (Rasorite®), and will be used in boric acid production when new facilities at Boron begin operation. Boric acid and anhydrous boric acid are currently manufactured at the U.S. Borax plant in Wilmington, California. These facilities will be shut down, however, when a new boric acid processing plant in Boron begins production. The new 182 Gg (200,000 tons/year) of boric acid/year plant will have more than twice the capacity of the Wilmington plant.[1,3]

Kerr-McGee Chemical Corporation operates two brine extraction plants located on adjacent sites near Searles Lake in California. Both the Trona and the Westend facilities extract borax and boric acid from lake brines, in addition to several nonborate compounds, including sodium sulfate. The Trona plant processes approximately 38 m^3 (10,000 gallons) of brine per minute, the Westend plant processes about 15 m^3 (4,000 gallons) per minute.[2]

Calcium borate (colemanite) and sodium/calcium borate (ulexite and probertite) ores are processed at the American Borate Co. plant located in Lathrop Wells, near Las Vegas, Nevada. The Lathrop Wells plant has just been expanded to include facilities for processing calcium borate by a new flotation process. These facilities, which have replaced part of the old washing facilities, have a capacity of 91 Gg of colemanite (100,000 tons) per year.[1,4] Ulexite and probertite are very similar compounds which are typically sold as one compound.

The boric acid facilities in San Francisco are operated by Stauffer Chemical Company. These facilities use refined borax obtained from U.S. Borax to supply approximately 5 percent of the market for boric acid.[5]

The location of each of these processing sites in indicated on the map in Figure 4-2.

4.3 PROCESS DESCRIPTION

Borate compounds are produced from calcium or sodium borate ores, or brine. The preparation of purified borax from sodium borate ore (tincal and kernite) principally involves separating the clay and shale impurities from the crushed ore. Borax is then used in dehydration, fusion, and acidification processes to produce boric acid and anhydrous derivatives of borax and boric acid. Figure 4-3 summarizes the refining and processing operations used in the production of borate compounds. Each of these processes is described in the following paragraphs.

4.3.1 Ore Processing

Borax products, such as borax decahydrate, borax pentahydrate, and anhydrous borax are refined from the sodium borate ore, tincal ($Na_2B_4O_7 \cdot 10H_2O$). The crude ore is a mixture of clay, shale, and borax, containing approximately 40 percent borax by weight.[3] During the refining process, about 85 percent of the borax is recovered from the clay and shale.[3] The ore is dissolved in a hot, weak borax solution, then passed through vibrating screens to remove large insoluble particles from the solution. The solution is then pumped to thickening tanks where the insoluble clay fines settle out. The clarified borax liquor is filtered and pumped to vacuum crystallizers. A centrifuge removes the borax crystals from the liquor. These crystals are then dried in gas-fired dryers to form either borax pentahydrate or borax decahydrate. Anhydrous borax is produced by first heating the borax in calciners to decrepitate the crystals into a powder, then melting the calcined borax in fusing furnaces at 1255 to 1366K (1800^{o} to 2000^{o}F) to form an

Figure 4-2. Location of borax/boric acid facilities.

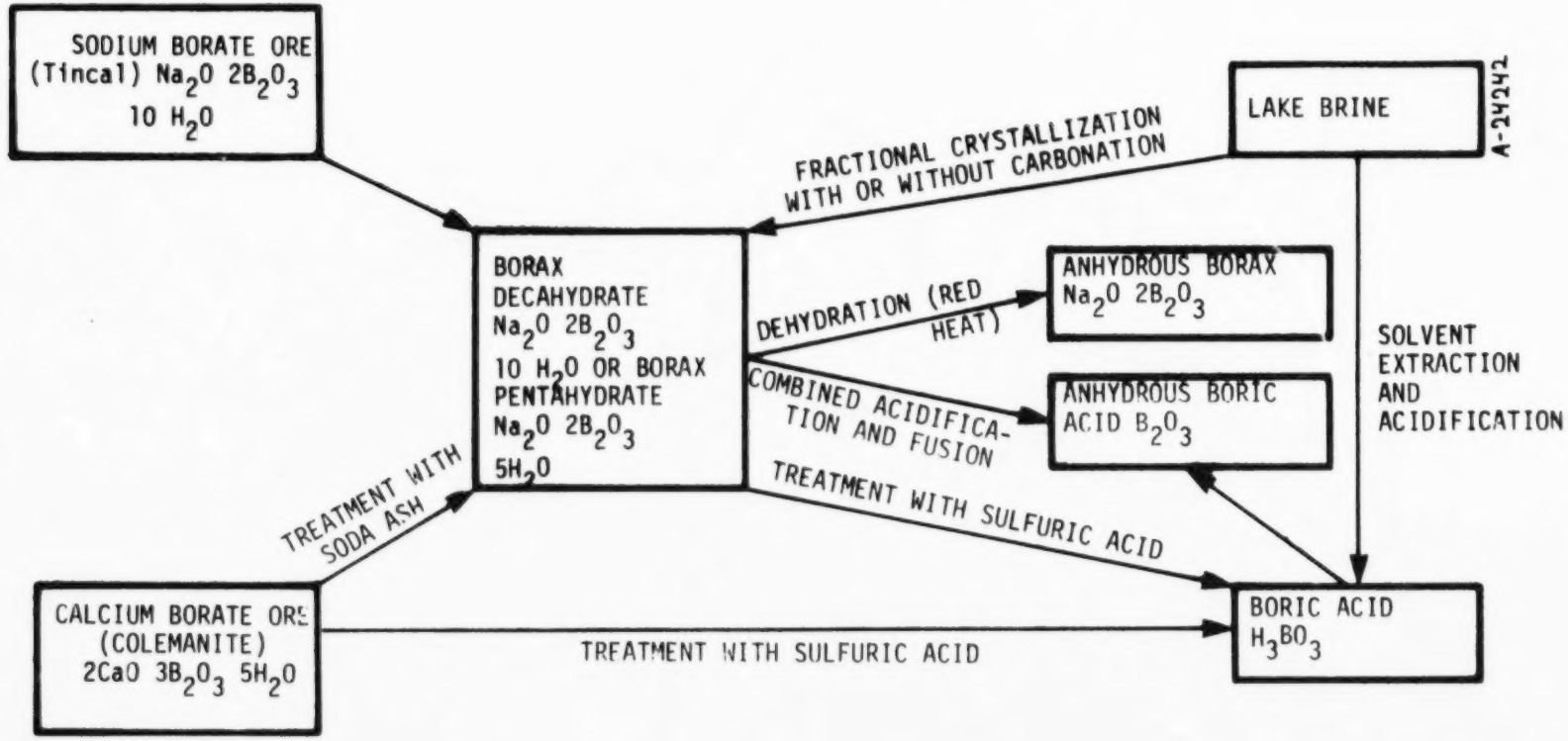


Figure 4-3. Refining and production of boron compounds.

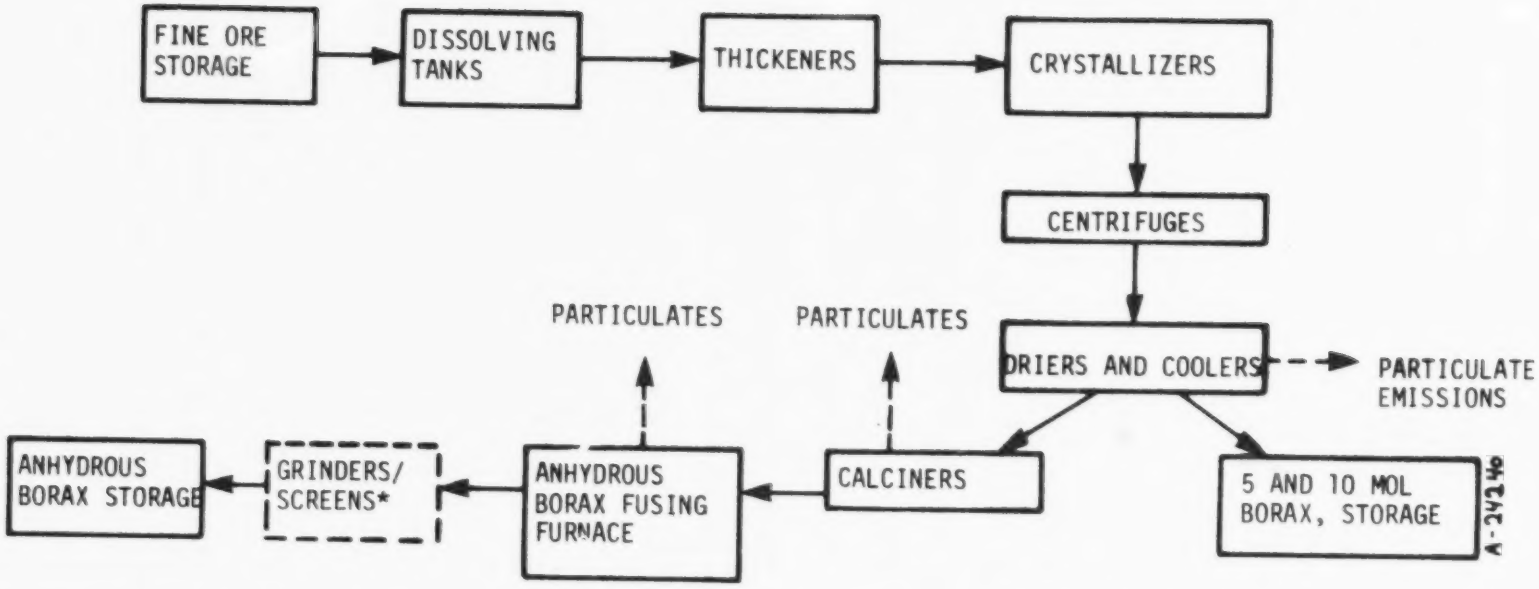
amorphous glass-like product. The anhydrous borax glass is crushed and screened prior to storage or shipment.

The refinement processes used on colemanite, a calcium borate ore, remove shale and clay contaminants by means of the flotation process (the details of which are confidential). The colemanite is then dried in a gas-fired rotary kiln dryer, and either calcined or sold as uncalcined product.[4]

Particulates are emitted from the fusing furnaces, dryers, calciners, and coolers (which are located after the dryers). Process flow diagrams for ore refining are given in Figures 4-4 and 4-5.

4.3.2 Brine Processing

Boraxes (both penta and decahydrate forms) are extracted from lake brines along with several other inorganic compounds. Two processes, carbonation and evaporation, produce borax as an endproduct. During the carbonation process, carbon dioxide is bubbled through the brine to precipitate soda ash. By neutralizing and cooling the remaining brine in vacuum crystallizers, borax crystals are formed. These crystals are dewatered and dried to form borax pentahydrate and borax decahydrate. Sodium sulfate is crystallized when the brine in the vacuum crystallizers is further cooled. During the evaporation process, rapid, controlled cooling is used to selectively precipitate halite (NaCl), sodium carbonate (Na_2CO_3) and potassium chloride (KCl). Borax crystals are formed when the remaining liquor is fed into crystallizer tanks containing borax seed crystals. These crystals are separated from the liquor in cyclones, then filtered, washed, redissolved, and recrystallized. The recrystallized product from the vacuum crystallizers is then separated in cyclones and



*EMISSIONS FROM THESE SOURCES ARE INCLUDED IN THE NON-METALLIC MINERALS SOURCE CATEGORY.

Figure 4-4. Borate ore refining.

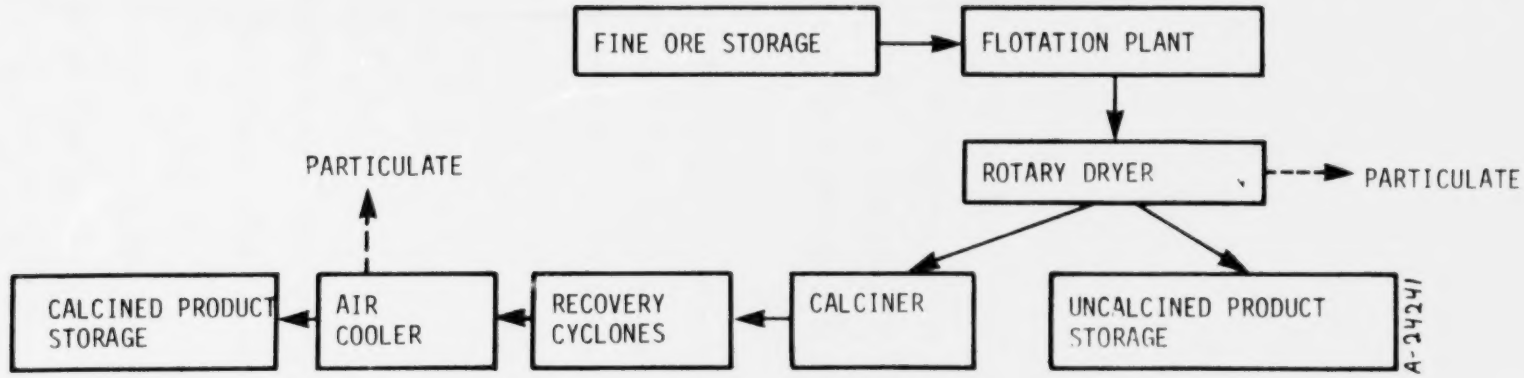


Figure 4-5. Colemanite ore processing.

dried to form borax. A portion of the borax is used as feed to calciners and fusing furnaces to produce anhydrous borax.

4.3.3 Boric Acid Production

Boric acid can be produced by either acidulation of borax, or by acid extraction from Searles Lake brines. Flow diagrams of these two processes are presented in Figures 4-6 and 4-7. In the borax acidulation process, which is used by both U.S. Borax and Stauffer, a hot saturated borax solution or finely granulated borax is reacted with sulfuric acid in an acidifier or digester. When the solution is cooled in vacuum crystallizers to the appropriate temperature, crystalline boric acid precipitates. Sodium sulfate is also recovered from the solution by crystallization at a slightly lower temperature. The filtered crystals may then be refined by recrystallization from water to produce pure boric acid.

Boric acid is recovered from weak Searles Lake brines by feeding recycled liquors from other processes along with the weak brines to an extraction system. The borates contained in the brine are extracted with a kerosene solution of a chelating agent, such as 2 ethyl-1,3 hexanediol. The chelated borates are contained in the organic phase, which is sent to a stripping mixer. In the stripping mixer, dilute sulfuric acid strips the borates from the chelate. The stripped organic phase, containing kerosene and chelating agent, is recycled to the extractor for reuse. The aqueous phase contains boric acid and sulfate compounds. Any organics contaminating the boric acid solution are removed by treatment with activated carbon; the boric acid is then crystallized out of the solution in an evaporator/crystallizer. A second crystallizer is used to recover

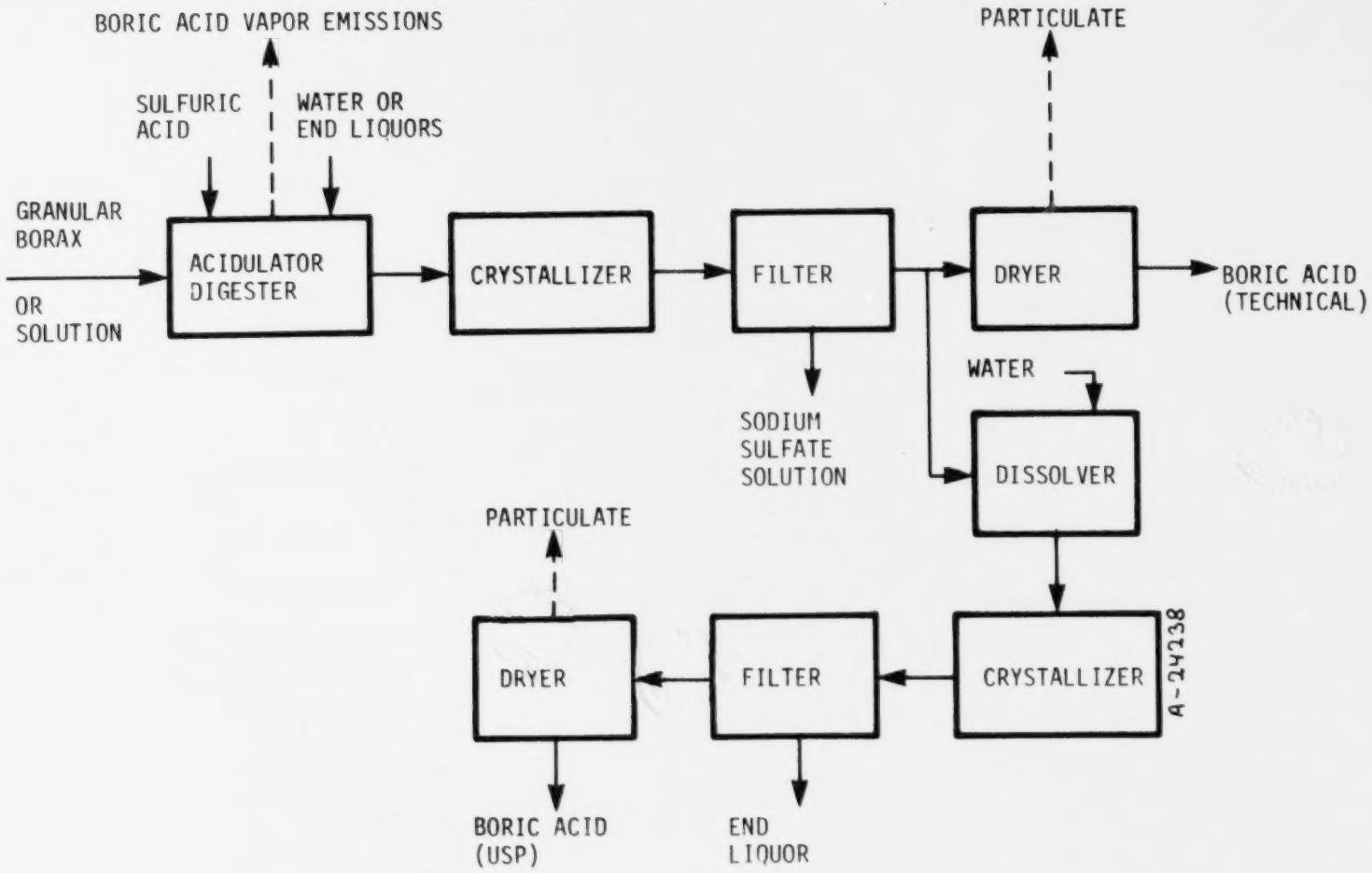


Figure 4-6. Boric acid production from borax by acidulation.

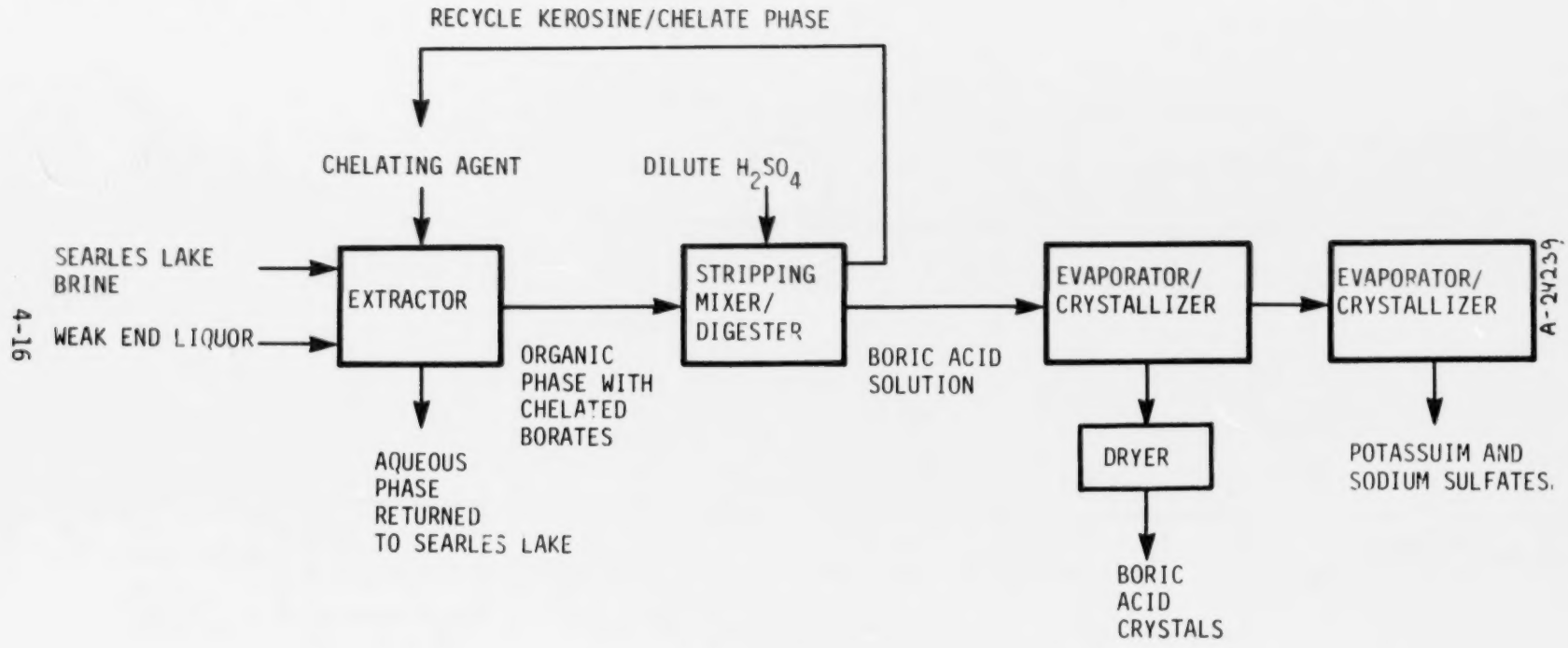


Figure 4-7. Boric acid production from weak brine.

the sulfates from the solution. A flow diagram of this process is presented in Figure 4-4.

The emission sources at boric acid facilities are the digesters, which emit boric acid vapors, and the dryers, which emit particulates.

5. AIR EMISSIONS DEVELOPED IN SOURCE CATEGORY

Air pollutants are released into the atmosphere during borate compound production. The production processes that release air contaminants have been discussed in Section 4.3. This chapter discusses the characteristics and quantities of the air pollutants and their impact on nationwide criteria pollutant emissions.

5.1 PLANT AND PROCESS EMISSIONS

Air pollutants are emitted by the fusing furnaces, calciners, dryers, and coolers. These emissions consist primarily of particulate matter; however, sulfur dioxide and nitrogen oxides, which are generated as a result of fuel combustion, are also emitted. Additionally, boric acid vapors are released from the digesters during boric acid production.

It is assumed that complete combustion is achieved in all the combustion sources and hence that hydrocarbon and carbon monoxide emissions are negligible; however, no test data on these pollutants are available to substantiate this.

5.1.1 Particulate Emissions

The exhaust gases from dryers, coolers, calciners, and fusing furnaces typically are laden with borate compound particulate matter. The contribution to particulate emissions due to fuel combustion is negligible since natural gas and distillate oil are the fuels commonly used.[6]

In general, the quantity of particulate emissions released depends on the product desired. The production of anhydrous borax or boric acid generates more particulate emissions than that of hydrated borates since the former requires processing the mineral through the calciner and fusing furnace in addition to the dryer. Based on data from one plant, 96 percent of the particulates emitted by the dryers are retained on 325 mesh sieve, which corresponds to 44 μm (0.0017 in.) particle diameter. It is estimated that approximately 20 to 30 percent of the particles emitted from the calciner are in the submicron size range. These particles are lightweight (density of approximately 15 kg/m^3 (0.94 lb/ft^3)) and white.[7]

Particulates are emitted from the fusing furnace during the descent of the feed material (calcined borates) and as the borates are melted. These emissions, therefore, contain calcined borate particles and anhydrous borates. Particles exiting the furnace have a mass median diameter of 14 μm according to one source.[7]

Typical SIP regulations for this source category require that particulate emissions not exceed 0.23 g/nm^3 (0.1 gr/scf) from new or modified facilities and 0.46 g/nm^3 (0.2 gr/scf) from existing facilities.[8] Controlled emission rates from typical new dryers, calciners, and fusing furnaces in compliance with these regulations are shown in Table 5-1, along with uncontrolled emissions. Uncontrolled particulate emissions are calculated using emission factors generated in Reference 9.

5.1.2 Nitrogen Oxide Emissions

During combustion processes, NO_x emissions are formed both due to oxidation of the nitrogen in the fuel and due to fixation of nitrogen and

Table 5-1. PARTICULATE EMISSIONS FROM TYPICAL FACILITIES[9]

Facility	Typical production rate, Mg/h	(tons/hr)	Uncontrolled particulate emissions[a]				Controlled emissions to meet a typical SIP[c]			
			kg/h	(lb/hr)	Mg/h[b]	(tons/yr)	kg/h	(lb/hr)	Mg/h[b]	(tons/yr)
Dryer/cooler	10.88	(12)	125	(278)	1104	(1217)	5	(11)	44	(49)
Calciner	9.07	(10)	106	(232)	920	(1014)	7	(15)	60	(66)
Fusing furnace	7.26	(8)	85	(186)	745	(822)	6	(13)	52	(57)

[a]From Reference 1.
[b]Assumes 8750 hours of operation.
[c]The Kern County Air Pollution Control District of California regulations.

oxygen in the combustion air (thermal NO_x). Oxidation of fuel nitrogen is insignificant in borate compound processing since the fuels burned (natural gas and distillate oil) contain little or no nitrogen. The NO_x emissions from calciners depend on the amount of dehydration which, in turn, depends upon the heat release rate from the burner, if the calciner is equipped with its own burner. In many cases, however, the material in the calciner is heated using the hot off-gases from the fusing furnace. In these cases, calciners do not generate oxides of nitrogen.

The fusing furnaces, where temperatures as high as 1366K (2000°F) exist, are expected to generate NO_x emissions.[7,10] No data, however, are available on the amount of NO_x emitted from fusing furnaces. No control measures for nitrogen oxide emissions have been implemented on any of the borax and boric acid plants.

5.1.3 Sulfur Oxides Emissions

Emissions of sulfur oxides are generated by the combustion of sulfur in the fuel. Although distillate oil is used in production processes, the sulfur content in the distillate oil is limited by two factors. First, regulations in California, where approximately 90 percent of borax and boric acid is produced (see Chapter 4), limit sulfur content in the fuel to 0.2 percent.[8] And secondly, the sulfur oxides from combustion can potentially react with the sodium borates and thus form undesirable sodium sulfates. Due to these limitations, SO_2 emissions from borax and boric acid production can be expected to be low. No data are available, however, on SO_2 emissions measurements from borax and boric acid production.

5.2 TOTAL NATIONAL PARTICULATE EMISSIONS

Controlled particulate emissions from borax and boric acid plants are shown in Table 5-2. These emissions were estimated by the state and local air pollution control agencies for the year 1978.

Total controlled particulate emissions generated during borate compound processing amount to 619 Mg (682 tons) per year.[11]

Table 5-2. NATIONWIDE PARTICULATE EMISSIONS FROM BORAX AND BORIC ACID PRODUCTION

Plant	Controlled particulate emissions (1978)	
	Mg/yr	tons/yr
A	530	584
B	34	38
C	11	12
D	8	9
E	33	36
F	<3	<3
Total	619	682

6. CONTROL TECHNOLOGIES

6.1 CURRENT CONTROL TECHNIQUES

Particulate emission control equipment has been in use on borate compound processing facilities for the past decade. The main particulate emission sources have been the fusing furnaces; however, the dryers, coolers, and calciners also emit particulates. Boric acid vapor emissions from digesters are typically controlled in order to recover the valuable acid. No controls have been used to reduce either NO_x or SO_x emissions. Table 6-1 summarizes the controls used for each of the emission sources.

6.1.1 Fusing Furnace and Calciner Controls

Wet scrubbers are the most common particulate control devices used in reducing emissions from both anhydrous boric acid (boric oxide) and anhydrous borax (pyrobor) fusing furnaces; however, an electrostatic precipitator has been used in one instance. Typically the same control device also controls emissions from the calciner. Scrubbers with pressure drops ranging from 4.4 kPa to 10 kPa (17.5 to 44 in. WC) have been used to reduce fusing furnace emissions to compliance levels.[7,10]

A venturi scrubber controlling fusing furnace emissions at one plant has reported an efficiency of 97.5 percent in removing particles having a mass median diameter of 14 μm.[10]

Table 6-1. EMISSION CONTROL SYSTEMS

Facility	Control	Operating parameter
Borax dryer	Venturi scrubber Fabric filter	
Colemanite dryer	Fabric filter	A/C = 6:1
Boric acid dryer	Multivane scrubber Fixed throat venturi scrubber	
Fusing furnace and calcines	Orifice scrubber Adjustable throat venturi scrubber High energy wet scrubber Electrostatic precipitator	Δ P = 7 kPa (28 in. WC) Δ P = 4.4-4.7 kPa (17.5-19 in. WC) Δ P = 8.7-10 kPa (35-40 in. WC) 22 KVA
Boric acid digester	Wet scrubber	

Fusing furnace exhaust gas temperatures at this source range from 1255 to 1366K (1800° to 2000°F). These gases are cooled by quenching with scrubber liquor to about 340K (153°F) before entering the venturi scrubber. The pressure drop across the venturi is maintained at about 10.7 kPa (43 in. WC) by varying the throat diameter between 0.64 cm to 25.4 cm (0.25 to 10 in.). The scrubber operates at a liquid to gas ratio of 1.65 l/m^3 (0.01 gal/ft^3). About 33 l/s (520 gal/min) of scrubbing liquor are used to treat 20 m^3/s (43,000 acfm) of furnace exhaust gas. Although the scrubbing liquor is recycled, approximately 28 l/s of fresh water needs to be added to maintain the borax concentration between 10 and 15 percent. A 746 kW (1000 hp) blower moves the gas through the scrubbing system. This blower is capable of handling 44 m^3/s (93,500 acfm) of gas at 357K (184°F) and 11.2 kPa (45 in. WC) pressure drop. A cyclone entrainment separator separates the scrubbing liquor from the gas in the scrubber effluent stream.[10]

Two other high energy scrubbing systems applied to borax fusing furnaces at another plant are designed to handle incoming gas streams of 33 m^3/s (70,000 acfm) and 47 m^3/s (100,000 acfm) at temperatures between 450 and 533K (350° to 500°F). These scrubbers operate at pressure drops of 8.7 kPa (35 in. WC) and 10 kPa (40 in. WC) and reduce emissions to meet a 0.23 g/Nm^3 (0.1 gr/scf) emission standard. The fans required to push the gas through these scrubbers use between 746 and 1119 kW total power (1000 and 1500 horsepower).[7]

6.1.2 Product Dryers and Coolers

Emissions from product dryers frequently are ducted to coolers, and therefore control equipment is typically located downstream of the coolers, where the emissions are released to the atmosphere. Both wet

scrubbers and fabric filters have been used to control particulate emissions. Fabric filters, however, have in some applications been replaced with scrubbers because of difficulties in maintaining bag temperatures above the dew point.[3] Efficiencies up to 99 percent on wet scrubbers have been reported.[12] Data on scrubber pressure drops used in this application are not available.

6.1.3 Mixers, Reactors, and Evaporators

Boric acid vapors are typically emitted by the evaporators during boric acid production. These emissions are typically controlled by wet scrubbers; boric acid is recovered from the scrubber effluent. No data on scrubber operating parameters are available.

6.2 ALTERNATE CONTROL TECHNIQUES

Fabric filters and electrostatic precipitators (ESP's) have both been used to a limited extent on borate compound processing equipment. ESP's, which have been used on pyrobar fusing furnaces and calciners, cannot continuously achieve regulatory limits. Plant operators have attributed the poor performance of the ESP's to excessive particle resistivity.

Fabric filters have been used on borate compound dryers and calciners to recover the product from the dryer or calciner exhaust gas, as well as for emission control. A fabric filter operating on a colemanite dryer uses a cyclone precleaner and operates at an air to cloth ratio of 6:1.[4] Nomex bags are used to handle the 422K (300^{o}F) gas. Frequently the same filter also controls emissions from screening and conveying operations. However, due to the hygroscopic characteristics of the particulate matter, the particles tend to form a cake which blinds the bags when temperatures drop below the dewpoint with resulting moisture condensation. In some cases where operators have had difficulty

maintaining the temperature above the dewpoint, filters are being replaced by wet scrubbers. Glass fiber filter bags have been successful in reducing fusing furnace emissions in pilot scale tests, but have not been used on full size furnaces to date.

7. PARTICULATE EMISSIONS DATA

Particulate emissions measurements have been made at many of the borax and boric acid production plants. The measurements were made to evaluate whether emissions were in compliance with the applicable air pollution control regulations of the respective states or air pollution control districts. Table 7-1 summarizes the relative amount of data available on air emissions from all six borax and boric acid production plants at the state or local air pollution control agency offices.

Large borax and boric acid plants such as those operated by U.S. Borax and Kerr-McGee have their own testing crews which make emissions measurements for internal company use. These emissions data, obtained from the company during recent plant visits, are shown in Table 7-2 along with typical emission data available from the control agency. The test methods used for internal company measurements do not necessarily adhere to acceptable EPA practice. In many cases, the company's crew only makes one or two runs to complete the test. Sampling and analysis of the particulate emissions by local and state agencies are reported to be performed according to EPA Method 5, however, this has not been confirmed.

Table 7-1. THE DATA AVAILABILITY ON PARTICULATE EMISSIONS

Plant/location	Air pollution control agency	Availability of of useful data
U.S. Borax and Chemical Corporation, Boron, CA	Kern County Air Pollution Control District	Substantial data available. Many of the processes tested.
U.S. Borax and Chemical Corporation, Wilmington, California	Southcoast Air Quality Management District	Data exists, however, available only with prior permission from the plant management
Kerr-McGee Chemical Corporation, Trona, CA	Southcoast Air Quality Management District	Data exists, however, available only with prior permission from the plant management
Kerr-McGee Chemical Corporation, Westend, California	Southcoast Air Quality Management District	Data exists, however, available only with prior permission from the plant management
American Borate Co., Lathrop Wells, Nevada	Nevada Department of Conservation	No data exists since no tests performed after the completion of expansion/ renovation of the plant
Stauffer's Chemical Co. San Francisco, CA	Bay Area Air Pollution Control District	Limited data available

Table 7-2. PARTICULATE EMISSIONS

Plant	Affected process	Source of data	Particulate emissions rate, g/nm^3 (gr/dscf)	Date of testing	Reported test method
A	Rotary dryer No. 1 for production of sodium borate decahydrate	Kern County Air Pollution Control District	0.034 (0.015)	Apr. 1976	EPA Method 5
	Rotary dryer No. 4 for production of sodium borate decahydrate		0.085 (0.037)	Apr. 1976	EPA Method 5
	Rotary dryer No. 5 for production of sodium borate decahydrate		0.096 (0.042)	Apr. 1976	EPA Method 5
	Rotary dryer for production of sodium borate pentahydrate		0.172 (0.075)	Apr. 1976	EPA Method 5
	Calcining and cooling (combined)		0.052 (0.023)	Apr. 1976	EPA Method 5
	Fluid bed dryer		0.019 (0.0083)	Nov. 1978	EPA Method 5
B	Anhydrous borax furnace No. 1	Company	0.088 (0.0384)	Jun. 1972	Not known
			0.098 (0.0429)	Jun. 1972	Not known
			0.269 (0.1173)	Jul. 1972	Not known
	Anhydrous borax furnace No. 2	Company	0.085 (0.0373)	Jun. 1972	Not known
			0.107 (0.0467)	Jun. 1972	Not known
			0.062 (0.0279)	Jun. 1972	Not known
	Anhydrous borax furnace No. 3	Company	0.062 (0.0272)	Jun. 1972	Not known
			0.0095 (0.0414)	Jun. 1972	Not known
			0.0852 (0.0372)	Jun. 1972	Not known
C	Boric acid dryer	Southcoast Air Quality Management District	0.057 (0.0250)	Oct. 1976	EPA Method 5
	No. 2 and No. 3 pyrobor furnace		0.627 (0.2740)	Oct. 1976	EPA Method 5
	Dryer No. 2		0.150 (0.0697)	Oct. 1976	EPA Method 5
	Dryer		0.038 (0.0165)	Oct. 1976	EPA Method 5

8. STATE AND LOCAL EMISSIONS REGULATIONS

Regulations do exist governing air emissions from borax and boric acid production as a part of the SIP to attain or maintain national ambient air quality standards. This chapter presents relevant state and local regulations, the degrees of controls required due to them and enforcement of these regulations.

8.1 SUMMARY OF REGULATIONS

Air pollution regulations affecting borax and boric acid production exist in the states of California and Nevada. Although several other states have regulations that could be applicable to borax and boric acid production, no production facilities for borax and boric acid as defined in this source category are known to exist in those states. Table 8-1 shows the respective plants and the air pollution control agencies having jurisdiction.

Air pollution control regulations for new or modified borax and boric acid production facilities are presented in Table 8-2 for the states of California and Nevada. The regulations have been presented for particulate matter only since it is considered the only major pollutant emitted from this source category (see Chapter 5).

Table 8-1. BORAX AND BORIC ACID PLANTS AND GOVERNING CONTROL AGENCIES

Plant/location	Control agency
U.S. Borax Boron, CA	Kern County Air Pollution Control District, State of California
U.S. Borax Wilmington, CA	Southcoast Air Quality Management District, State of California
Kerr-McGee Trona, CA	Southcoast Air Quality Management District, State of California
Kerr-McGee Westend, CA	Southcoast Air Quality Management District, State of California
American Borate Lathrop Wells, NV	State of Nevada, Department of Conservation
Stauffer San Francisco, CA	Bay Area Air Pollution Control District, State of California

Table 8-2. SUMMARY OF STATE AND LOCAL REGULATIONS (PARTICULATE MATTER)

Control agency state/county	Affected facility	New or modified source regulation
California/Kern County Air Pollution Control District	Dryer Calciner Fusing furnace	0.23 g/nm^3 (0.1 gr/dscf), or $E = 1.73\ p^{0.62}$ ($E = 3.59\ p^{0.62}$) if $p \leq 27.2$ (30) $E = 7.98\ p^{0.16}$ ($E = 17.31\ p^{0.16}$) if $p < 27.2$ (30) whichever is stringent, where, E = emission rate, kg/h (lb/hr) p = process weight, Mg/h (tons/hr) Opacity limited to 20 percent
California/Southcoast Air Quality Management District	Dryer Calciner Fusing furnace	0.23 g/nm^3 (0.1 gr/dscf) corrected to 12 percent CO_2 Opacity limited to 20 percent
Nevada	Dryer and calciner combined	0.31 kg/Mg (0.62 lb/tons)[a] Opacity limited to 20 percent
California/Bay Area Air Pollution Control District	Dryer Fusing furnace	0.34 g/nm^3 (0.15 gr/dscf) and, $E = 1.99\ p^{0.67}$ ($E = 4.10\ p^{0.67}$) where, E = emissions rate, in kg/h (lb/hr) not to exceed 18.2 kg/h (40 lb/hr) and p = process weight rate Mg/h (tons/hr) Opacity limited to 20 percent

[a]This rule applicable to American Borate Co., Lathrop Wells, Nevada only.

The State of California regulations differ from other states' regulations in that local air pollution control districts comprising of one or more counties promulgate regulations affecting facilities under their jurisdiction. These regulations, however, are promulgated only after state approval under the State Implementation Plan. The enforcement activities concerning these regulations are also delegated to individual air pollution control districts.

The State of Nevada regulation affecting new or modified sources was recently promulgated through the revision of its State Implementation Plan. The rule was revised to restrict particulate emissions from one borax production plant which planned expansion and renovation of its facility. The State of Nevada estimates that due to this new regulation, the overall controlled particulate emissions from the plant were reduced from 106 Mg (118 tons) in 1977 to 41 Mg (46 tons) in 1978 after expansion.[13]

8.2 DEGREE OF CONTROL REQUIRED BY REGULATIONS

The particulate emissions control requirements in the State of Nevada are the most stringent of all the regulations affecting borax production. The degree of control required, as indicated in Table 8-3, is 0.31 kg/Mg (0.62 lb/ton).

Table 8-3 also presents the degree of control required under the Kern County Air Pollution Control District regulations. Over 75 percent of the borax/boric acid produced would be governed by these regulations.

8.3 EXTENT OF ENFORCEMENT

In the State of Nevada and California, compliance with particulate regulations is presently verified through plant inspections, opacity observations, and performacne tests. Plant inspections include inspection

Table 8-3. DEGREE OF CONTROL REQUIRED AT THE TWO MOST STRINGENTLY CONTROLLED PLANTS

State/local agency	Affected facility	Uncontrolled[a] emission rate		SIP (new source) emissions rate	
		kg/Mg	lb/ton	kg/Mg	lb/ton
Nevada	Dryer and calciner combined	11.6	23.2	0.31	0.62
Kern County	Dryer[b]	11.6	23.2	0.46	0.92
	Calciner[c]	11.6	23.2	0.75	1.50
	Fusing[d] furnace	11.6	23.2	0.82	1.62

[a]Uncontrolled emission rate based on Reference 1.
[b]Assuming process weight rate of 11 Mg/h (12 tons/hr) through the dryer.
[c]Assuming process weight rate of 9 Mg/h (10 tons/hr) through the calciner.
[d]Assuming process weight rate of 7 Mg/h (8 tons/hr) through the fusing furnace.

of the equipment and equipment maintenance records. The opacity observations are made periodically by duly certified opacity observers. Opacity observations and equipment operation and maintenance records are used as guides in determining whether performance tests should be made. The permit to operate is then renewed only after source test results verify compliance.

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13. Telecon. Raisoni, R., Acurex Corporation with Hugh Ricci, Nevada Environmental Protection Division. September 27, 1979.

APPENDIX A

PERSONS WITH EXPERTISE IN THE BORAX/BORIC ACID INDUSTRY IDENTIFIED DURING SOURCE CATEGORY SURVEY

Industry contacts	Title	Address	Phone number
U.S. Borax and Chemical Corporation			
Mr. Roger Olmsted	Senior Environmental Engineer[a]	U.S. Borax and Chemical Corporation 3075 Wilshire Blvd. Los Angeles, CA 90010	(213) 381-5311
Mr. Hsueh-Pei Liu	Senior Engineer	U.S. Borax and Chemical Corporation Boron, CA 93516	(714) 762-5167
Kerr-McGee Chemical Corporation			
Mr. V. Stanley Clift	Manager, Plant Engineering	Kerr-McGee Chemical Corporation Trona, CA 93562	(714) 372-4011
Mr. C. P. Roberts	Chief Project Engineer	Kerr-McGee Chemical Corporation Trona, CA 93562	(714) 372-4011
Mr. J. W. Jenney	Sales Representative[a]	Kerr-McGee Chemical Corporation 2975 Wilshire Blvd., Suite 425 Los Angeles, CA 90010	(213) 385-3356
American Borate			
Mr. Richard Walters	Manager of Process Engineering	American Borate Co. 3311 South Jones Blvd., Suite 212 Las Vegas, NV	(702) 871-7707
Other Contacts Ms. Sandra T. Absolom	Physical Scientist	U.S. Bureau of Mines 2401 E St. NW Washington, D.C. 20241	(202) 634-1177

[a]Corporate office contact for arranging plant visit.